FIRST DETECTION OF THERMAL H_2O EMISSION FROM A HERBIG-HARO OBJECT

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Abstract. The first detection of thermal H_2O emission from an Herbig-Haro flow was made with the LWS (Long Wavelength Spectrometer) aboard ISO (Infrared Space Observatory). In addition to H_2O, rotational lines of CO and OH as well as lines from [O I] and [C II] were also recorded from HH 54. These observations are consistent with the concept of interstellar shock waves, but a quantitative unifying shock model, capable of explaining all observations, has yet to be developed.

1. Introduction

Star forming molecular clouds are exciting astronomical objects, to the physicist and the chemist alike. Numerical modeling of the complex, interdependent physical and chemical processes has been hampered, though, by our incomplete knowledge of the abundances of gas phase key-molecules (e.g. van Dishoeck et al. 1993). This is particularly true for H_2O, primarily due to severe observational difficulties even at balloon altitudes (e.g. Tauber et al. 1996 and references therein). The Long Wavelength Spectrometer (LWS) aboard the Infrared Space Observatory (ISO) is therefore a particularly well suited instrument for such observations.

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[1] The complete author list, including affiliations, can be found in the *Special ISO Issue* of Astronomy and Astrophysics 315, L181

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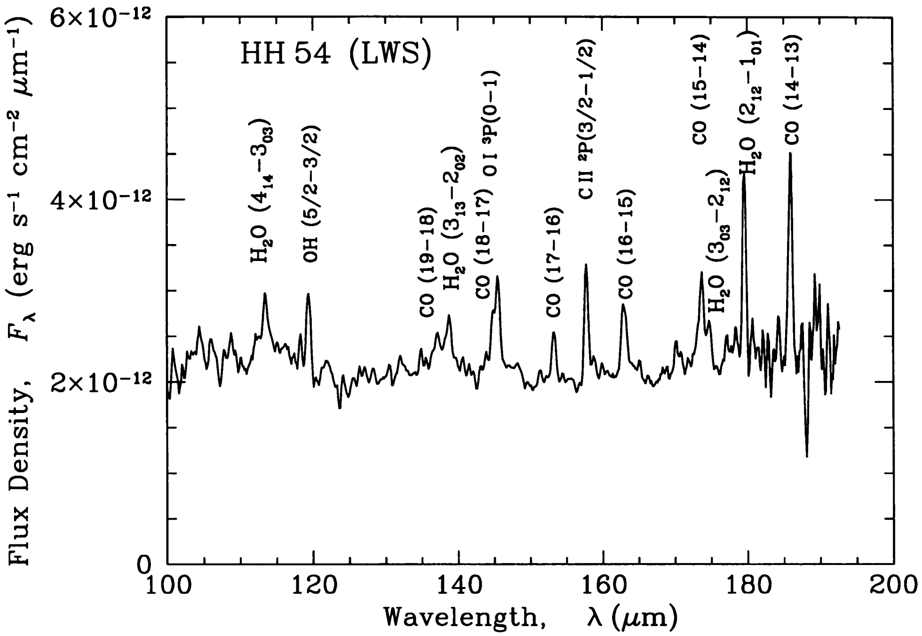

Figure 1. Part of the LWS spectrum ($R \sim 200$) of HH 54 with emission lines identified.

2. Observations and results

Strong water emission is predicted by numerical models of dense interstellar shocked gas (Hollenbach & McKee 1989, Kaufman & Neufeld 1996). HH 54 in the star-forming dark cloud Cha II is probably associated with shocked gas (see Gredel 1994 and references therein) and was observed during the LWS Guaranteed Time. The long-wave part of the far infrared spectrum of HH 54 is displayed in Fig. 1, showing atomic and molecular emission lines superposed onto a continuous background.

3. Discussion and conclusions

The observed spatial distribution and line strength of [C II] 158 μm is consistent with photo-ionization of atomic carbon by the interstellar radiation field, whereas the [O I] 63/145 μm emission is compatible with the predictions of existing J-shock models (Nisini et al. 1996). However, assuming that our estimate of the pre-shock gas density, $n_0(H_2) < 10^4\,cm^{-3}$, is correct, these models would currently fail to reproduce also the observed molecular line emission; apparently, time dependent models in non-planar geometries

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are required to simultaneously explain *all* observations (Gredel 1994, Liseau et al. 1996). The latter authors fitted the observed far infrared molecular line emission with a simple model of HH 54, the parameters and results of which are summarized in Table 1.

Of particular interest may be our estimates of the relative molecular abundances in HH 54, viz. CO:H_2O:OH$\sim$100:10:1, and the finding that these species practically provide the entire cooling of the shock heated gas (v_s of order 10 km s^{-1}).

TABLE 1. HH 54: LVG-model parameters and results for CO, OH and H_2O

Kinetic temperature	T_{kin}	(330 ± 30) K
Particle density	$\log n(H_2)$	5.3 ± 0.2 cm^{-3}
Column density	$N(H_2)$	$5.0\,10^{20}$ cm^{-2}
Thickness of layer	dr	$2.5\,10^{15}$ cm
Mass	$M(H_2)$	$6.8\,10^{-3}$ $M_\odot$
Line width	dv	10 km s^{-1}
Background radiation	T_{bg}	2.735 K
Diffuse dust field	T_{dust}	15 K $[\beta = -1.5, \lambda(\tau = 1) = 3\,\mu m]$
Beam filling	f_b	$(10 \pm 2)^{-1}$ (80″ LWS-beam)
Source size	θ_{CO}	25″ − 30″ (0.03 pc at 250 pc)
CO abundance	$X(CO)$	$8\,10^{-5}$
CO cooling rate	L_{CO}	$1.0\,10^{-2}$ $L_\odot$
H_2O abundance	$X(H_2O)$	$1\,10^{-5}$ (ortho/para = 3)
H_2O cooling rate	L_{H_2O}	$2.0\,10^{-3}$ $L_\odot$
OH abundance	$X(OH)$	$1\,10^{-6}$
OH cooling rate	L_{OH}	$1.0\,10^{-3}$ $L_\odot$
Radiative losses	$L(CO + OH + H_2O)$	$1.3\,10^{-2}$ $L_\odot$
Mechanical power	$\frac{1}{2}\,\rho_0\,v_s^3 \times area$	$1.8\,10^{-2}$ $L_\odot$ ($v_s = 10$ km s^{-1})

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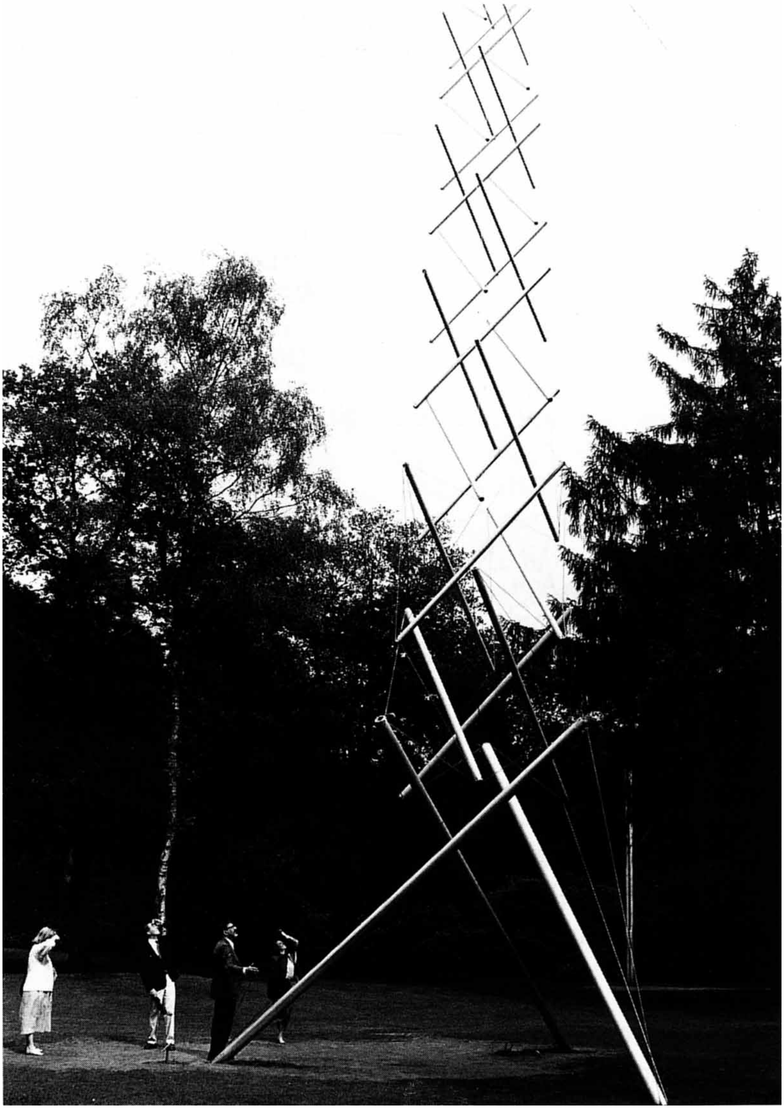

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